

Case Report

# Sustaining Immunization Under the Roar of Cannons: Lessons Learned from Sudan, June 2023 to December 2024

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## Abstract

**Background:** Immunization is known to be a cost-effective intervention; addressing more than (20) diseases. The Expanded Program on Immunization (EPI) was established to ensure target population, especially children, benefit from life-saving immunization services. Securing resources, establishing systems, and demand generation are crucial for successful immunization programs. The ongoing conflict in Sudan, resulting in displacement of over 10 million people, had severely affected country's immunization services. This study explores the impact of the conflict on Sudan's EPI and examines the strategies employed to mitigate these challenges. **Methods:** A qualitative synthesis and desk review were conducted to explore the best practices, innovations, challenges, and lessons learned from June 2023- to December 2024. Five of the authors collaborated to identify sources and extracted data from the EPI reports and records. Two other authors verified the outcomes and complemented it using meeting memos. Compiled findings were shared with other authors for review and feedback. Data was manually organized and analyzed using a thematic analysis. Key themes reflected the situation of EPI program before the conflict, the impact of war on the program, and the response of EPI program. Thematic areas encompassed human resources, cold chain, routine immunization, supplementary immunization activities, surveillance and outbreak investigation. **Results:** By the end of 2024, the EPI in Sudan started to reverse the decline in immunization services' coverage and accessibility resulting from war. Modification of service delivery strategies; contemplating the security status district by district was key success factor. Furthermore, program's resilience was supported by a dedicated, committed, and responsive EPI teams at national and sub-national levels, operating in collaboration and coordination with partners, motivated by a unified vision encapsulated in the slogan "Despite what is happening, vaccination must continue". **Conclusions:** To sustain the immunization services in Sudan, the EPI prioritized the cohesion and solidarity of the team, adopting a collaborative approach. This durable essence of unity was especially evident in expanding partnership in security compromised states.

## Keywords

Immunization, Sudan, Conflict, Achievement, Lesson Leant

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## 1. Introduction

Immunization is a cost-effective investment to the prevention and control of more than 20 vaccine preventable diseases (VPDs) [1]. Immunization has significantly reduced infectious diseases' morbidity and mortality. Childhood vaccines are estimated to save 4 to 5 million lives every year and have positively impact cognitive development, schooling, and economic productivity [2]. That is why the immunization agenda for 2030 stresses expanding equitable access to immunization services for all ages, across life-course [2].

The EPI, established in 1974, ensures that all children and adults worldwide, benefit from life-saving vaccines. Countries implement their own EPI programs; initially prioritizing 6 diseases (Bacillus Calmette-Guérin (BCG), diphtheria, pertussis, tetanus, poliomyelitis, and measles). Overtime, priority disease has expanded, and the World Health Organization (WHO) now recommends 13 vaccines (antigens) for national EPI programs' schedules. National health priorities, disease burden and local contexts guide selection of antigens for national schedules, spanning entire life course, providing protection from infancy through childhood, adolescence, and into older adulthood. To achieve EPI objectives and set targets, countries must establish basic program elements. These include adequate human resources at all levels, proper supply and logistics management system, suitable service delivery strategies, system for monitoring immunization coverage and adverse events following immunization (AEFIs), disease surveillance and demand generation interventions. [3] Moreover, countries must ensure that the vaccine supply and service delivery are adequately integrated in the existing health system and that the health care providers advocate for immunization at all levels. [4].

Conflicts affect immunization coverage by damaging infrastructure and interruption of supply and service delivery systems at the PHC level including EPI. The risk of VPDs outbreak increases as conflicts create conditions favoring disease transmission such as population displacement, malnutrition and over-crowding [5] Considerable percentage - may be up to 40% - of under-vaccinated children live in areas that are either partially or entirely affected by conflicts [6-8].

In Pakistan, the EPI faces several challenges in conflict affected areas such as lack of clarity about the delivery strategy - whether fixed centres, outreach or mobile teams, scarcity of human resource, inaccurate target calculations, logistical and financial obstacles, lack of political commitment, and community misconceptions about vaccines [9]. In Ethiopia, the immunization program had seriously deteriorated during and after the conflict due to security challenges, displacement of health workers, destruction of health infrastructures, integration of the displaced community in the host community, and weak coordination among stakeholders and partners [10].

The Ministries of Health in conflict affected areas usually

seek the help of UN agencies and Non-Governmental Organization (NGOs). UNICEF is known to play an important role, negotiating corridors of peace and days of tranquility with armed groups that allow vaccinators to deliver immunization. Moreover, it supports resilient system strengthening and capacity building, ensuring uninterrupted supply of vaccines, improved risk communication and community engagement and tailored integrated outreach strategies [7].

In Sudan, the challenges faced by the immunization program are not markedly different from those observed in other conflict-affected settings. Recent published reports underscore the complexity of vaccinating target groups in Sudan amidst the current war, highlighting the need for innovative funding mechanisms and adaptive service delivery strategies. [11] This study aims to present how the EPI program in Sudan has addressed the consequences of war on immunization services. Main challenges encountered, approaches adopted, key achievements, lessons learned are examined, proposing the way forward.

## 2. Methodology

**Study area:** The Republic of the Sudan lies in Sub-Saharan Africa, and is the third largest country in the continent, with a land area of 1,886,068 square kilometres. As of 2019, Sudan's population is estimated at 42,596,5891. The country has a coastal line along the Red Sea and shares borders with seven countries: Egypt, Eritrea, Ethiopia, South Sudan, the Central African Republic, Chad, and Libya, most of these are elevated risk countries for VPDS. Sudan is a multiracial, multicultural nation distributed along eighteen states and 189 localities.

**Setting:** As of April 15<sup>th</sup>, Sudan has been enduring an armed conflict affecting Khartoum - the capital and Darfur and Kordofan zones, rapidly expanding to reach central states, Gezira, Sennar, White Nile and Blue Nile, by the end of 2024. This widespread conflict resulted in a mass displacement with over 10 million displaced people, out of which 1.5 million crossed borders with neighboring countries.

EPI program in Sudan is a cornerstone of PHC, delivering one of the most effective preventive health interventions. One of the most notable achievements of the program is its expansion of immunization schedule, reflecting on a life course approach. The program started with 6 antigens and reached 11 antigens by the end of 2024, including introduction of Meningococcal A (MenA), Pneumococcal Conjugate Vaccine (PCV), Inactivated Polio Vaccine (IPV), Yellow Fever (YF), and a second dose of Measles Vaccine (MV2). Sudan is free of poliomyelitis for 16 years and succeeded to contain of circulating vaccine-derived poliovirus type 2 (cVDPV2). Major achievement also includes mitigation of measles risk, and reduction of other VPDs in addition to rapid to cholera outbreaks.

**Design:** In this retrospective description, a qualitative synthesis and desk review of the EPI during the emergency period from June 2023 to December 2024 was conducted; aiming to identify the best practices, innovations, challenges, and lessons learned to inform future programming.

**Data collection and analysis:** five of the authors identified relevant sources and extracted data from the EPI reports and records. The outcome was verified by two additional authors, using their meeting memos. The team shared their findings with the broader author team for review and feedback. All comments were compiled and integrated in the final analysis. Data was manually organized and analyzed using a thematic analysis approach.

**Ethical consideration:** As the data used in this study was collected from a public health program, including aggregated reports and documents, ethical clearance was not required. Permission to use the data was obtained from PHC General Directorate at Federal Ministry of Health (FMOH) in Sudan [12] Also, consent was not specifically sought for this study, as the analysis was based on anonymized data and all personally identifiable information were removed prior to reporting.

### 3. Results

The findings of this study highlight the situation of Sudan's EPI program prior to the conflict, the consequences of war on the program, and the response strategies implemented. The analysis is structured around key components including the human resources, cold chain, routine immunization (RI) and supplementary immunization activities (SIAs), and vaccine preventable diseases (VPDs) surveillance and response. The conflict resulted in a very dynamic situation and unstable environment characterized by challenging security and polit-

ical conditions with subsequent consequences on human resources, service accessibility, and health infrastructure.

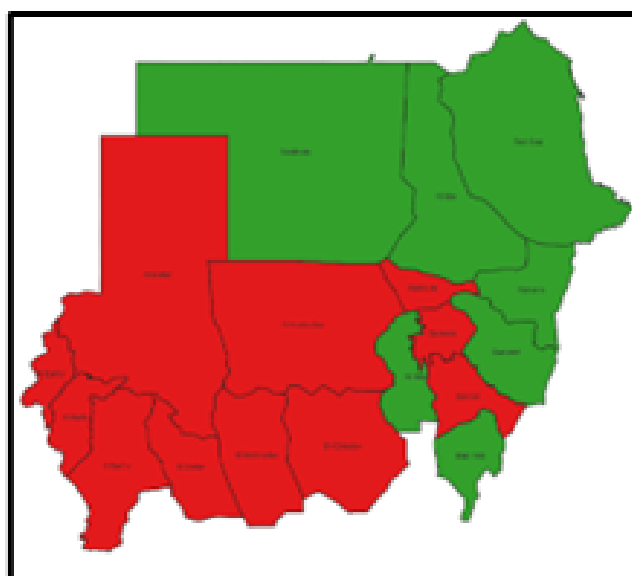
#### 3.1. Human Resources - The EPI Team

Before the conflict EPI in Sudan was operated under a robust encompassing a national team and 18 sub-national teams. While the national EPI team included 85 personnel, state level teams were composed of EPI managers and officers responsible for RI, SIAs, cold chain logistics, and disease surveillance. In addition, there are vaccinators whose immunization is the primary role, reflecting a strong human resources component of the program (EPI micro-plan 2024).

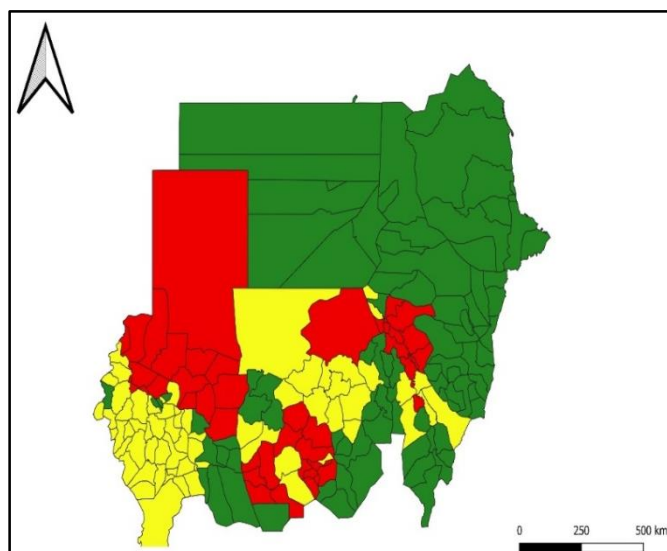
The EPI program is further supported by national independent advisory and oversight committees such as the National Immunization Technical Advisory Group (NITAG), the National Certification Committee (NCC), the Adverse Event Following Immunization (AEFI) committee, the National Expert Committee (NEC), and the National Containment Committee.

Like the general population, the EPI teams at national and states levels were directly affected by war. Tragically, at least three EPI personnel lost their lives, many others were not able to reach their working stations or were preoccupied by their own selves' and families' safety. Others run short of vaccines to sustain services. In addition, government instability adversely affected the operation of the program.

This was further aggravated by the destruction and looting of the state's EPI offices, stores and vehicles. The program lost more than 57 vehicles including vaccine trucks. Moreover, 11 states were totally inaccessible or hard to reach with 51 localities (districts) partially accessible and 22 totally inaccessible (Figure 1). This directly affected EPI managerial and vaccinators teams.



a. Accessibility by state: Accessible (green) and Hard-to-Reach states (Red).



b. Accessibility by locality: Accessible (green), partially accessible (yellow) and inaccessible (red) localities.

**Figure 1.** Accessibility status of states and localities, Sudan EPI, 2024.

Even though, the war in Sudan compromised the life of everyone in Khartoum, the national EPI team, supported by PHC management responded swiftly. On the first day of the tragedy, the EPI team in collaboration with partners formulated a small crisis management group to assess the feasibility of evacuating the supplies from the national vaccine store in Khartoum anticipating challenges in electricity supply maintenance. Subsequently in June 2023, a core team was formed in Wad Madani, a safe city at that time, initially composed of 9 personnels and later the team expanded to 19 experts. Driven with a sound and easy to share slogan “*Despite what is happening, vaccination must continue*”, the national team initiated and maintained communication with states teams and partners and proved its resilience and capacity to respond rapidly to emerging issues.

### 3.2. The Cold Chain

The documented success of EPI in Sudan since its establishment is largely attributed to sustaining an efficient cold chain and supply system. In addition to the central cold chain unit in Khartoum, there were 21 units at state levels. Each designed to meet the vaccination needs of the target population, including the routine service and supplementary immunization activities.

Due to widespread looting and the complete or partial destruction of facilities and equipment, the program lost its main vaccine stores representing about 42% of total capacity. The first store affected was the central store which is located south of Greater Khartoum, near where the fighting first erupted. The teams on duty were not able to rotate shifts due to the security situation.

Standby generators were used due to electricity instability; however, this was challenged by a shortage of fuel. Over time, worries about losing vaccines was a reality. The cold chain unit in Khartoum State was the second to be affected followed by the unit in South Darfur state. As the conflict progressed, more units were affected across Darfur, Kordofan, and central Sudan regions, extending to reach facility level. As a result, approximately 315 pieces of equipment were lost, leading to disruption of vaccine supply system from central to state to locality and health facility levels.

Despite the active military operations in Khartoum State, the EPI team in collaboration with partners succeeded to evacuate the vaccines. A total of 6.9 million doses of routine immunization vaccines and 6 million doses of measles-rubella (MR) vaccines were evacuated safely from the central store to a newly established store in Wad Madani and subsequently distributed to other states. Concurrently, the EPI team and its partners exerted tremendous efforts to maintain the integrity of the cold chain across all states, particularly in security compromised states. These efforts included the establishment of 5 new cold chain units.

During the study period, the cold chain succeeded to distribute 16 million doses of RI vaccines to the states. In addition, 5 million doses of Oral Cholera Vaccine (OCV) were supplied to control cholera outbreaks across six states. Furthermore, 14.5 million doses of MR vaccine availed for MR campaigns and for MR routine immunization. The efforts prioritized supplies to most vulnerable, and conflict affected areas such as Khartoum, Kordofan and Darfur (Figure 2). A joint convoy transported RI supplies from Kosti to Kordofan and to Darfur.



**Figure 2.** Pictures reflecting the efforts of the core team (left) and the vaccinators.

### 3.3. The Routine (RI) and Supplementary Immunizations Activities (SIA)

Over the past two decades, Sudan had sustained high RI coverage due to staff dedication, political commitment, coordination, and support from key partners including Global Alliance for Vaccine and Immunization (GAVI), UNICEF, WHO, and NGOs. Service delivery strategies including fixed, outreach, and mobile sites were used simultaneously. Alongside, efforts to maintain population immunity through SIAs are ongoing with plans targeting poliomyelitis, measles, and COVID-19.

Due to security situation, connectivity challenges, loss of assets - such as looted vehicles - and vaccines stock outs, only 62% (4,648) of vaccination centers remained functional, with only 33% of RI reports collected. The situation further deteriorated due to delayed disbursement of funds of operational costs of the RI activities resulting from difficulties in cash transfer.

Furthermore, the widespread population displacement has made it difficult to estimate population targets eligible for

vaccination. This coupled with families' priorities shifting towards shelter and food, deprioritizing immunization. An extensive disruption in the implementation of the RI sessions was reported, with the coverage by different antigens declining dramatically (Table 1). Furthermore, The SIAs were not implemented as planned.

Based on comprehensive assessment of the security situation and health system status, the EPI team and its partners classified the states into two groups according to the accessibility level. Group A (accessible states) includes Northern, River Nile, Blue Nile, White Nile, Gedarf, Kassala, and Red Sea States and Group B are hard to reach states that include Khartoum, Gezira, Sennar, North Kordofan, South Kordofan, West Kordofan, North Darfur, South Darfur, Central Darfur, East Darfur, and West Darfur (see Figure 1). Further classification - left map on Figure 1 - categorized Sudan's 186 localities to accessible (113 localities), partially accessible (51 localities), and inaccessible (22 localities). It is important to note that the accessibility status of states and localities is being continuously monitored. Due to the dynamic nature of the situation, classifications are subject to change over time as conditions evolve on the ground.

**Table 1.** Coverage with Penta 1 and Penta 3 per state, Sudan EPI, Dec 2024.

| States      | 2022    |         | 2023    |         | 2024    |         |
|-------------|---------|---------|---------|---------|---------|---------|
|             | Penta 1 | Penta 3 | Penta 1 | Penta 1 | Penta 1 | Penta 3 |
| Northern    | 101     | 99      | 107     | 101     | 108     | 107     |
| River Nile  | 99      | 95      | 104     | 99      | 112     | 107     |
| Red Sea     | 82      | 69      | 100     | 95      | 104     | 96      |
| Kassala     | 92      | 81      | 88      | 83      | 97      | 89      |
| Gedarif     | 100     | 94      | 87      | 82      | 117     | 106     |
| Blue Nile   | 96      | 81      | 91      | 67      | 85      | 63      |
| White Nile  | 96      | 85      | 93      | 79      | 85      | 69      |
| Sennar      | 100     | 94      | 94      | 64      | 81      | 69      |
| Gezira      | 92      | 81      | 96      | 93      | 27      | 24      |
| Khartoum    | 96      | 85      | 28      | 25      | 17      | 14      |
| N. Kordofan | 88      | 84      | 49      | 39      | 36      | 23      |
| S. Kordofan | 95      | 96      | 56      | 46      | 56      | 58      |
| W. Kordofan | 109     | 92      | 53      | 47      | 8       | 5       |
| N. Darfur   | 100     | 94      | 38      | 29      | 19      | 11      |
| S. Darfur   | 99      | 89      | 14      | 8       | 32      | 8       |
| W. Darfur   | 100     | 91      | 44      | 34      | 45      | 38      |
| E. Darfur   | 82      | 69      | 25      | 31      | 36      | 21      |
| C. Darfur   | 92      | 80      | 28      | 23      | 26      | 17      |
| Sudan       | 94      | 84      | 57      | 51      | 48      | 39      |

The team finalized an emergency plan adopting a differentiated approach and customized strategies to counteract the challenges imposed by the new situation. The plan aims to increase demand for EPI services, ensure adequate supplies,

and build capacity of program's personnel. Additionally, Context-specific delivery strategies were adopted for each state and locality. (Table 2).

**Table 2.** Health system readiness, target population, challenges and adapted vaccination strategies according to accessibility classes, Sudan, 2024.

| Class and access level         | Health system readiness | Target    | Key challenges                                                                                                    | Adapted strategies                                                            |
|--------------------------------|-------------------------|-----------|-------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------|
| States                         |                         |           |                                                                                                                   |                                                                               |
| Group A (Accessible states)    | High                    | 491,559   | IDPs, rainy season, change of the target population                                                               | Regular outreach<br>Fixed site services maintained<br>PIRI                    |
| Group B (Hard-to-reach states) | Moderate/ low           | 1,364,814 | Intermittent access, security threats, severe conflict, supply chain disruptions, change of the target population | Mobile health units<br>Community-led campaigns<br>Temporary vaccination posts |

| Class and access level | Health system readiness | Target  | Key challenges                                                                             | Adapted strategies                                                   |
|------------------------|-------------------------|---------|--------------------------------------------------------------------------------------------|----------------------------------------------------------------------|
| Localities             |                         |         |                                                                                            | Use of local mediators<br>Hit and Run<br>PIRI                        |
| Accessible             | High                    | 842,089 | IDPs, rainy season, change of the target population                                        | Regular outreach<br>Fixed site services maintained                   |
| Partially accessible   | Moderate                | 660,372 | Intermittent access, security threats, IDPs, rainy season, change of the target population | Mobile health units<br>Community-led campaigns                       |
| Inaccessible           | Low                     | 327,854 | Severe conflict, supply chain disruptions, change of the target population                 | Temporary vaccination posts<br>Use of local mediators<br>Hit and run |

Following the initiation of the implementation of the emergency plan, the RI was restored and SIAs started to progress. By December 2024, the coverage with BCG, Penta 1, Penta 3, Measles Containing Vaccine (MCV)/MR1, and MCV/MR2 significantly increased in Group A states (accessible), however, for Group B states (hard-to-reach) it remained below target. During the annual review meeting, the EPI teams at national and states levels decided to engage more partners to overcome the persistent challenges in hard-to-reach states. By the end of December 2024, the coverage for Penta 1 and Penta 3 started to reverse the down-going trend (Figure 3) in many states. Concurrently, more than 3 million under 5 children were vaccinated against poliomyelitis in 8 states. Moreover, more than 5.7 children were vaccinated against measles and rubella, which was facilitated introduction of MR vaccine in RI in 8 states.

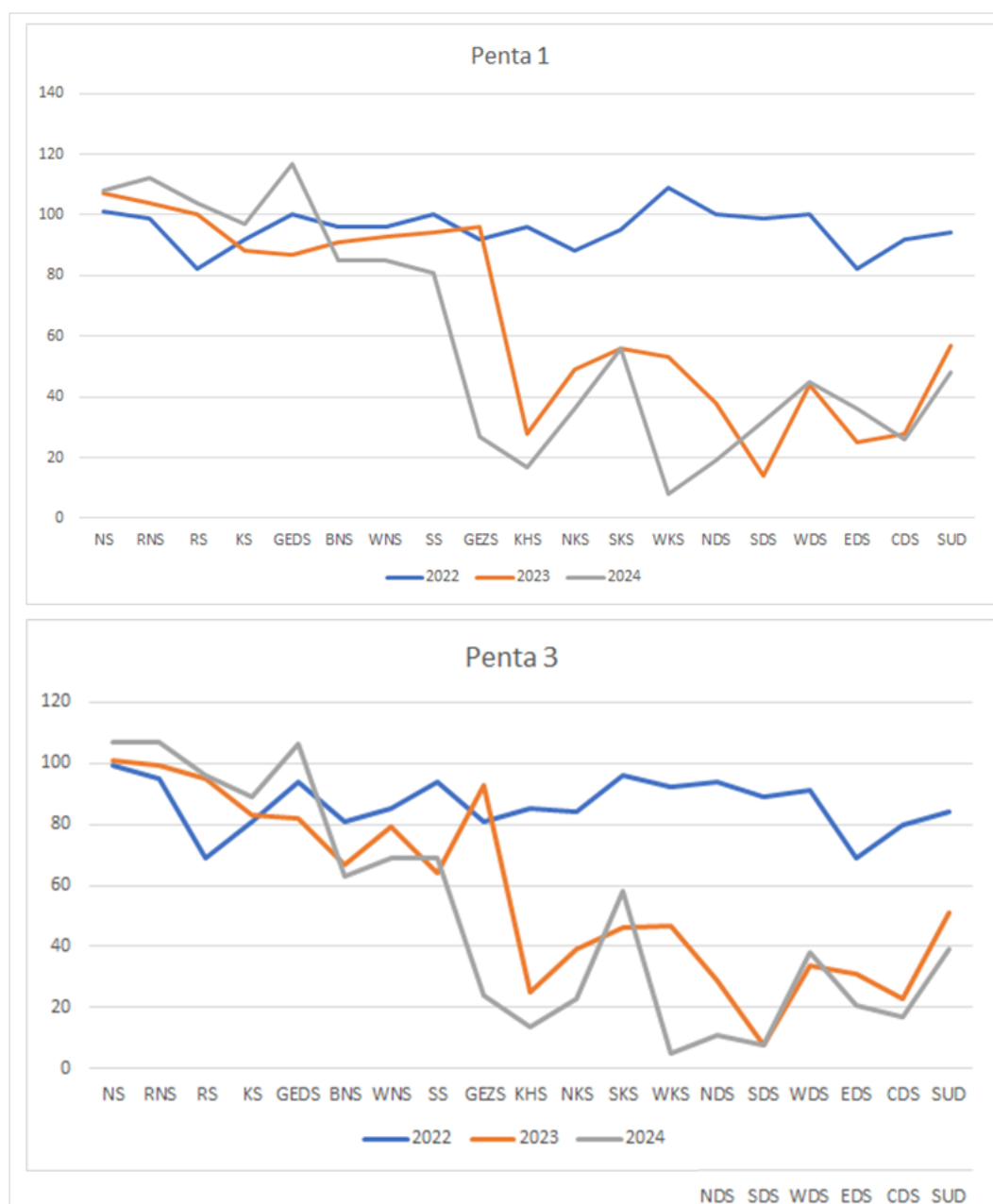
In response to the cholera outbreak that began in August 2023 and affected 37 localities across 7 states by the end of 2024, the EPI program in collaboration with the Health Emergency and Epidemic Control General Directorate, implemented a series of vaccination campaigns to control the outbreak aimed at controlling the outbreak. The response campaign was organized into 9 phases: each covering a target geographical area. In total, 11.96 million people were vaccinated (with a coverage rate of 93.4%) in Gedarif, Gezira, Khartoum, Red Sea, Kassala, White Nile, River Nile, Sennar,

and Northern States.

A breakthrough and outstanding achievement were the introduction of two new vaccines; measles-rubella (MR) and malaria vaccine. The roll out of MR vaccine was introduced in phases considering the security situation in Sudan. In phase one, eight states were targeted: River Nile, Northern, Red Sea, Kassala, Gedarif, Blue Nile, Sennar and White Nile states. A total of 6,851,121 children aged 9 months to less than 15 years were vaccinated (a coverage rate of 102%). Phased two focused on partially accessible states. Karrari locality in Khartoum states and two localities in Gezira state were covered with a total of 470,647 individuals vaccinated with a coverage rate of 94.3% and 801,013 individual vaccinated with a coverage rate of 98%, respectively.

The EPI program in collaboration with the national malaria control program and partners succeeded to introduce malaria vaccine (R21/Matrix-M vaccine) into RI services, targeting children under one year. The vaccine was used in phased manner which was guided by the burden of malaria at locality level. As part of phase one, the vaccine introduction was launched on November 4<sup>th</sup>, 2024, in Gedarif and Blue Nile states targeting 16 localities. Phase two aims to expand to 147 priority localities by the end of 2026.

Other vaccine introduction efforts aim to introduce Hep-B Birth Dose targeting Infants 0 - 14 days).



**Figure 3.** Coverage with Penta 1 and Penta 3 per state, Sudan EPI, 2022 - 2024.

### 3.4. The VPDs Surveillance and Response to Outbreaks

Sudan's EPI has a strong vaccine-preventable diseases (VPDs) surveillance system. The system is based on reports from 963 sentinel sites across the country. To fill the identified surveillance gap in some states, a newly established community-based surveillance (CBS) trained 568 community volunteers. Additionally, there is a well-established central laboratory unit within the National Public Health Laboratory (NPHL) which is equipped with sampling kits and clear protocols for samples collection and transportation. The effectiveness of the system is reinforced by strong stakeholder

engagement, including active participation from pediatricians, healthcare providers, facility-level focal persons, and EPI surveillance officers at all administrative levels.

The ongoing conflict has severely affected the immediate and weekly reporting due to disruption of the government system, staff displacement, and connectivity issues. At the time of the study, only 623 out of 963 (65%) sentinel sites 200 out of 577 (35%) community volunteers are reporting regularly. Reporting rates from hard-to-reach states was low averaging 40% (251 out of 577) in recent months.

The national laboratory unit at the NPHL was not functioning, and the stock of sample kits at states and facilities was depleted due to inaccessibility to the central store. These challenges have resulted in delayed detection and confirma-

tion of suspected (and probable) cases of measles, whooping cough, diphtheria, cholera, and acute flaccid paralysis (AFP). Moreover, sample collection and transportation were discontinued. Thus, the timely response to the outbreak was jeopardized.

Efforts to enhance surveillance and early detection of VPDs include training of additional community volunteers and revitalization of sentinel sites in accessible and hard-to-reach states. One initiative in collaboration with EMPHNET is the Public Health Empowerment Program (PHEP) which targets EPI surveillance officers at locality level in 9 states. The program aims to build capacities in surveillance, outbreak investigation and project design, implementation and evaluation. Preliminarily, improvement in the overall reporting rates was observed (Table 3).

### 3.5. Social and Behavioral Communication (SBC)

Since establishment of the EPI in Sudan, efforts to increase demand for immunization, overcoming rumors, informing the

caregivers, and to address behavioral and social determinants (BeSD) are continuing. The EPI program utilizes a wide range of communication channels such as radio, TV, newspapers, immunization ambassadors, vaccination friends' groups, social media, health care providers, vaccinators among others.

However, the ongoing conflict in Sudan disrupted these efforts. Traditional and digital media channels have been affected safety concerns limit mobility of immunization teams. Moreover, The conflict shifted the families' priorities towards safety, securing shelters and food at the expense of routine immunization.

In coordination with the Health Promotion Directorate, with support from UNICEF, several interventions were implemented to mobilize communities and maintain and increase demand for routine immunization in the accessible states. These include training EPI teams and health promotion officers on crisis on communication during conflict. Additionally, mobile theatres for displaced people and host communities, home visits, orientation of religious and community leaders, and awareness session for general population were implemented.

**Table 3.** Status of reporting as part of vaccine preventable diseases surveillance system, 2023-2024.

| State       | April 2023- June 2023 |                         |                        |                       |                                | July 2023- December 2024 |                         |                        |                       |                                |
|-------------|-----------------------|-------------------------|------------------------|-----------------------|--------------------------------|--------------------------|-------------------------|------------------------|-----------------------|--------------------------------|
|             | ## of sites           | ## of functioning sites | % of functioning sites | ## of reporting sites | % Reporting out of functioning | ## of sites              | ## of functioning sites | % of functioning sites | ## of reporting sites | % Reporting out of functioning |
| Northern    | 65                    | 0                       | 0                      | 0                     | 0                              | 65                       | 65                      | 100                    | 65                    | 100                            |
| River Nile  | 84                    | 0                       | 0                      | 0                     | 0                              | 84                       | 84                      | 100                    | 84                    | 100                            |
| Red sea     | 53                    | 0                       | 0                      | 0                     | 0                              | 53                       | 53                      | 100                    | 53                    | 100                            |
| Kassala     | 43                    | 0                       | 0                      | 0                     | 0                              | 43                       | 43                      | 100                    | 43                    | 100                            |
| Gedarif     | 56                    | 0                       | 0                      | 0                     | 0                              | 56                       | 56                      | 100                    | 56                    | 100                            |
| Blue Nile   | 33                    | 0                       | 0                      | 0                     | 0                              | 33                       | 28                      | 85                     | 28                    | 100                            |
| White Nile  | 53                    | 0                       | 0                      | 0                     | 0                              | 53                       | 53                      | 100                    | 49                    | 92                             |
| Sennar      | 33                    | 0                       | 0                      | 0                     | 0                              | 33                       | 33                      | 100                    | 33                    | 100                            |
| Gezira      | 102                   | 0                       | 0                      | 0                     | 0                              | 102                      | 80                      | 78                     | 80                    | 100                            |
| Khartoum    | 108                   | 0                       | 0                      | 0                     | 0                              | 108                      | 22                      | 20                     | 22                    | 100                            |
| N. Kordofan | 64                    | 0                       | 0                      | 0                     | 0                              | 64                       | 56                      | 88                     | 56                    | 100                            |
| S. Kordofan | 32                    | 0                       | 0                      | 0                     | 0                              | 32                       | 27                      | 84                     | 27                    | 100                            |
| W. Kordofan | 42                    | 0                       | 0                      | 0                     | 0                              | 42                       | 22                      | 52                     | 22                    | 100                            |
| N. Darfur   | 47                    | 0                       | 0                      | 0                     | 0                              | 47                       | 7                       | 15                     | 7                     | 100                            |
| S. Darfur   | 52                    | 0                       | 0                      | 0                     | 0                              | 52                       | 52                      | 100                    | 52                    | 100                            |
| W. Darfur   | 55                    | 0                       | 0                      | 0                     | 0                              | 55                       | 43                      | 78                     | 43                    | 100                            |
| E. Darfur   | 30                    | 0                       | 0                      | 0                     | 0                              | 30                       | 30                      | 100                    | 30                    | 100                            |
| C. Darfur   | 59                    | 0                       | 0                      | 0                     | 0                              | 59                       | 50                      | 51                     | 30                    | 60                             |

| State | April 2023- June 2023 |                         |                        |                       |                                | July 2023- December 2024 |                         |                        |                       |                                |
|-------|-----------------------|-------------------------|------------------------|-----------------------|--------------------------------|--------------------------|-------------------------|------------------------|-----------------------|--------------------------------|
|       | ## of sites           | ## of functioning sites | % of functioning sites | ## of reporting sites | % Reporting out of functioning | ## of sites              | ## of functioning sites | % of functioning sites | ## of reporting sites | % Reporting out of functioning |
| Sudan | 1011                  | 0                       | 0                      | 0.0                   | 0                              | 1011                     | 804                     | 77                     | 780                   | 97.0                           |

3.6. Leadership and Management

Through the years, EPI in Sudan established a strong partnership with many organizations with clear definition of roles. While UNICEF is supporting cold chain, supply transportation, service delivery, monitoring, supervision, and SBC; WHO provides support for VPDs surveillance, outbreak investigation, response, and human resources for immunization. Save Children International (SCI) contributes to RI delivery, SBC, and supervision, while EMPHNET is active in capacity building. International Medical Corps (IMC) and AIGHT provide support in RI, integrated VPD services, SBC, cold chain (CC), and monitoring and evaluation (M&E), particularly in the Kordofan and Darfur regions. All partners provide continuous support for vaccination campaigns (MR, OCV, Polio, and response campaigns).

The EPI team strengthens the partnership with these organizations further with a clear shift towards emergency response. The EPI team actively involves the Minster of Health and the Director General of Primary Health Care in high-level communication within partner organizations and facilitate government-related processes.

Despite the challenges posed by the ongoing conflict, the EPI in Sudan has continued to operate through pre-existing coordination mechanisms that were well-established prior to the war. The Technical Working Group (TWG)—comprising representatives from WHO, UNICEF, SCI, Médecins Sans Frontières (MSF), EMPHNET, ACASUS, and the Project Management Unit (PMU)—has convened regularly to address emerging issues and guide programmatic decisions.

In addition, the EPI team has maintained its weekly RI coordination meetings with key partners, including UNICEF, WHO, and SCI. Weekly surveillance coordination meetings with WHO and other stakeholders have also continued, alongside the ACASUS-led electronic supervision meetings.

At the regional level, the Gavi Coordination Group, which includes technical staff from the regional offices of WHO, UNICEF, and EMPHNET, meets weekly to align and coordinate their activities with the national EPI program. The NITAG—comprising pediatricians, epidemiologists, microbiologists, researchers, representatives from the National Regulatory Authority, and development partners—has sustained its regular meeting schedule, continuing to provide evidence-based guidance for immunization policy and strat-

egy.

Furthermore, the EPI program actively engages health clusters, including OCHA, International Committee of the Red Cross (ICRC), MSF, and other humanitarian actors, to reach target populations in partially accessible and inaccessible areas. This coordination has extended to include collaboration with the Joint Military Forces in Darfur to facilitate the delivery of vaccines and supplies to areas under their control and beyond.

To strengthen subnational coordination, the EPI program has also established new coordination bodies at the state level, aimed at enhancing governance, accountability, and the effectiveness of immunization service delivery during emergencies.

Prior to the onset of the conflict, Sudan’s EPI operated a well-established M&E system. Data flowed systematically from the facility level to locality, then to state, and ultimately to the federal level, enabling comprehensive monitoring of immunization activities. Routine supervisory visits at all administrative levels complemented the reporting system, while periodic review meetings provided structured forums to assess performance, identify challenges, and implement corrective actions.

This monitoring framework was further supported by evaluation activities, including coverage surveys, post-campaign assessments, and operational research, which provided critical insights into program effectiveness and areas for improvement.

4. Discussion

The EPI program in Sudan has effectively reversed the decline in immunization coverage and improved access to services by adapting delivery strategies to the security context of each district. These efforts were supported by dedicated and responsive teams at both national and sub-national levels. The program’s success was further strengthened through strong collaboration with partners and a unified operational theme, encapsulated in the slogan: “*Despite what is happening, vaccination must continue.*” This collective effort was recognized through the awarding of the Medal of Achievement and Excellence by the Minister of Health and acknowledgment by the WHO Eastern Mediterranean Regional Office (EMRO).

Although the conflict in Sudan temporarily disrupted the

M&E system of the Expanded Program on Immunization (EPI), the system has since been partially restored. The federal EPI team demonstrated resilience and commitment by successfully conducting national supervisory visits in 17 out of 18 states. Additionally, supervisory activities related to the introduction of the malaria vaccine were implemented, reinforcing the program's capacity to adapt and maintain quality assurance during emergencies.

The ongoing conflict has significantly affected the immunization program by weakening public health infrastructure, diverting caregiver attention from preventive services, and prioritizing curative and emergency care. [10] As seen in other conflict-affected countries such as Afghanistan, the Democratic Republic of Congo, Somalia, and Angola, the long-term consequences of war often persist well beyond the cessation of hostilities. [13] Despite initial prioritization, rebuilding public health infrastructure, including immunization systems—rarely receives sustained investment. [14].

To mitigate the impact of conflict, the EPI program in Sudan implemented governance reforms, delegating greater authority to state-level actors, particularly in the design and execution of implementation strategies. This hybrid approach—combining top-down guidance with bottom-up engagement—proved effectively in enhancing immunization coverage and promoting local ownership. [14] Evidence from similar settings supports the effectiveness of institutional support, public education campaigns, countering misinformation, and maintaining coverage among host populations. [15].

Key strategies drawn from the Polio Eradication Initiative include: [9].

- 1) Conducting security assessments and negotiations with key actors,
- 2) Utilizing geographic information systems (GIS) for planning and tracking,
- 3) Engaging communities closely,
- 4) Coordinating with humanitarian relief efforts,
- 5) Adopting flexible vaccine scheduling and dosing strategies.

These approaches require coordinated efforts from local, national, and international stakeholders, underpinned by strong leadership and governance structures. Coordination of stakeholders and strong leadership systems are crucial in maintaining optimum vaccination service delivery even at the time of conflict [10].

WHO declared vaccine hesitancy as one of the world's top 10 global health threats in 2019 [16] Although vaccine hesitancy is not currently a widespread issue in Sudan, it remains a concern in contexts of migration and internal displacement. Among displaced populations, hesitancy has been linked to fear, misinformation, limited knowledge, and distrust. [17] This phenomenon has been observed in other countries and underscores the need for proactive communication and trust-building strategies. [18].

The conflict has contributed to the resurgence of VPDs

such as measles, diphtheria, cholera, and pertussis, as well as other infectious diseases like dengue fever and malaria. These outbreaks are driven by mass displacement, overcrowding, poor sanitation, lack of shelter, and malnutrition. [19] For example, Yemen experienced a fatal diphtheria epidemic in 2017 due to a significant drop in vaccine coverage. [20] Similarly, conflict in Afghanistan and subsequent displacement to Pakistan led to a rise in paralytic poliomyelitis cases, exacerbated by anti-vaccination propaganda and security threats. [21].

In conflict-affected areas, public health surveillance is often hindered by inaccessibility, infrastructure damage, and security constraints. These challenges can be addressed through the recruitment of local community volunteers who can negotiate access with armed groups and advocate for the urgent need for immunization and disease surveillance. The use of GIS technology is essential for mapping coverage, identifying gaps, and estimating the size and location of inaccessible populations. [22].

Two critical lessons emerged from the EPI program's experience during the conflict:

- 1) The early adoption of a collaborative approach enabled sustained communication with partners and alignment of activities, even as the conflict evolved and displacement patterns shifted.
- 2) Maintaining team cohesion and solidarity was essential for ensuring continued service delivery, particularly in areas directly affected by the conflict.

The EPI program and its partners are committed to sustaining routine immunization services not only in accessible areas but also in hard-to-reach and conflict-affected regions. This includes expanding partnerships in security-compromised states and extending services to zero-dose children under five years of age. Strengthening the capacity of EPI surveillance officers and frontline personnel through the expansion of the Public Health Empowerment Program (PHEP) equivalent to the basic Field Epidemiology Training Program (FETP) is a key priority. The goal is to maintain a functional VPD surveillance system, including community-based surveillance, and to ensure timely investigation and response to outbreaks.

Addressing the broader health crisis in Sudan requires international collaboration to restore healthcare services, improve living conditions, and strengthen disease surveillance. Timely and coordinated responses are essential to mitigate health risks and protect public health security.

#### 1. Limitation

To overcome the inherited pitfalls in such qualitative synthesis, we managed to strengthen the validity through triangulation of data and information from several sources including the program and partner documents.

## Abbreviations

AEFIs      Adverse Events Following Immunization

|       |                                                |
|-------|------------------------------------------------|
| AFP   | Acute Flaccid Paralysis                        |
| CBS   | Community-based Surveillance                   |
| EPI   | Expanded Program on Immunization               |
| EMRO  | WHO Eastern Mediterranean Regional Office      |
| FMoH  | Federal Ministry of Health                     |
| GAVI  | Global Alliance for Vaccines and Immunization  |
| MCV   | Measles Containing Vaccine                     |
| M&E   | Monitoring and Evaluation                      |
| MR    | Measles-rubella                                |
| MSF   | Médecins Sans Frontières                       |
| NCC   | The National Certification Committee           |
| NEC   | The National Expert Committee                  |
| NGOs  | Non-governmental Organizations                 |
| NITAG | National Immunization Technical Advisory Group |
| NPHL  | National Public Health Laboratory              |
| OCV   | Oral Cholera Vaccine                           |
| PHC   | Primary Health Care                            |
| RI    | Routine Immunization                           |
| SBC   | Social and Behavioral Change                   |
| SCI   | Save the Children International                |
| SIAs  | Supplementary Immunization Activities          |
| VPDs  | Vaccine Preventable Diseases                   |
| WHO   | World Health Organization                      |

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The data is available from the corresponding author upon

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## Conflicts of Interest

The authors declare no conflicts of interest.

## References

- [1] Ozawa S, Mirelman A, Stack ML, Walker DG, Levine OS. Cost-effectiveness and economic benefits of vaccines in low- and middle-income countries: A systematic review. *Vaccine*. 2012 Dec 17; 31(1): 96-108. <https://doi.org/10.1016/j.vaccine.2012.10.103>
- [2] WHO. Immunization Agenda 2030: A Global Strategy to Leave No One Behind [Internet]. 2020 [cited 2025 May 21]. Available from: <https://www.who.int/teams/immunization-vaccines-and-biologicals/strategies/ia2030>
- [3] World Health Organization (WHO). A guide for conducting an Expanded Program on Immunization (EPI) Review [Internet]. Geneva; 2017 [cited 2025 May 21]. Available from: <https://www.who.int/publications/i/item/WHO-IVB-17.17>
- [4] Shah MP, Morgan CJ, Beeson JG, Peach E, Davis J, McPake B, et al. Systematic Review Integrated Approaches for the Delivery of Maternal and Child Health Services with Childhood Immunization Programs in Low-and Middle-Income Countries: Systematic Review Update 2011-2020. 2024; 12: 1313. <https://doi.org/10.3390/vaccines12121313>
- [5] Ngo NV, Pemunta NV, Muluh NE, Adedze M, Basil N, Agwale S. Armed conflict, a neglected determinant of childhood vaccination: some children are left behind. Vol. 16, *Human Vaccines and Immunotherapeutics*. Taylor and Francis Inc.; 2020. p. 1454-63. <https://doi.org/10.1080/21645515.2019.1688043>
- [6] Bouaddi O, Seedat F, Hasaan Mohammed HE, Evangelidou S, Deal A, Requena-Méndez A, et al. Vaccination coverage and access among children and adult migrants and refugees in the Middle East and North African region: a systematic review and meta-analysis. *EClinicalMedicine*. 2024 Dec 1; 78. <https://doi.org/10.1016/j.eclim.2024.102950>
- [7] United Nations Children's Fund (UNICEF). UNICEF Immunization Roadmap 2018-2030 [Internet]. New York, NY 100017; 2018 [cited 2025 May 22]. Available from: [https://www.unicef.org/sites/default/files/2019-01/UNICEF\\_Immunization\\_Roadmap\\_2018.pdf](https://www.unicef.org/sites/default/files/2019-01/UNICEF_Immunization_Roadmap_2018.pdf)
- [8] Wigley A, Lorin J, Hogan D, Utazi CE, Hagedorn B, Dansereau E, et al. Estimates of the number and distribution of zero-dose and under-immunized children across remote-rural, urban, and conflict-affected settings in low and middle-income countries. *PLOS Global Public Health*. 2022 Oct 1; 2(10 October). <https://doi.org/10.1371/journal.pgph.0001126>
- [9] Haq Z, Shaikh BT, Tran N, Hafeez A, Ghaffar A. System within systems: Challenges and opportunities for the expanded program on immunization in Pakistan. *Health Res Policy Syst*. 2019 May 17; 17(1). <https://doi.org/10.1186/s12961-019-0452-z>

- [10] Asrade G, Alemu K, Gebeye E, Walle M, Teklu A, Mekonnen ZA, et al. The Burden of Internal Conflict on Expanded Programs on Immunization in Northwest Ethiopia: Implementation Science Study. Vol. 35. 2021.
- [11] Sabahelzain MM, Almaleeh A, Abdelmagid N, Abdalla O, Nor B, Mounier-Jack S, et al. Vaccination strategies to identify and reach zero-dose and under-immunized children in crisis-affected states in Sudan: a qualitative study. *Confl Health*. 2024 Dec 1; 18(1). <https://doi.org/10.1186/s13031-024-00639-9>
- [12] CIOMS and WHO. International ethical guidelines for health-related research involving humans [Internet]. Geneva: CIOMS; 2017 [cited 2025 May 22]. 122 p. Available from: <https://cioms.ch/wp-content/uploads/2017/01/WEB-CIOMS-EthicalGuidelines.pdf>
- [13] Obradovic Z, Balta S, Obradovic A, Mesic S. The Impact of War on Vaccine Preventable Diseases. *Materia Socio Medica*. 2014; 26(6): 382. <https://doi.org/10.5455/msm.2014.26.382-384>
- [14] Baatz RK, Ekzayez A, Najib Y, Alkhalil M, Salem M, Alshiekh MA, et al. Vaccination governance in protracted conflict settings: the case of northwest Syria. *BMC Health Serv Res*. 2024 Dec 1; 24(1). <https://doi.org/10.1186/s12913-024-11413-1>
- [15] Rzymiski P, Falfushynska H, Fal A. Vaccination of Ukrainian Refugees: Need for Urgent Action. Vol. 75, *Clinical Infectious Diseases*. Oxford University Press; 2022. p. 1103-8. <https://doi.org/10.1093/cid/ciac276>
- [16] World Health Organization (WHO). Ten threats to global health in 2019. 2019 [cited 2025 May 22]; Available from: <https://www.who.int/news-room/spotlight/ten-threats-to-global-health-in-2019>
- [17] Tankwanchi AS, Bowman B, Garrison M, Larson H, Wiysonge CS. Vaccine hesitancy in migrant communities: a rapid review of latest evidence. Vol. 71, *Current Opinion in Immunology*. Elsevier Ltd; 2021. p. 62-8. <https://doi.org/10.1016/j.coi.2021.05.009>
- [18] Nnadi C, Etsano A, Uba B, Ohuabunwo C, Melton M, Wa Nganda G, et al. Approaches to Vaccination among Populations in Areas of Conflict. *Journal of Infectious Diseases*. 2017 Jul 1; 216: S368-72. <https://doi.org/10.1093/infdis/jix175>
- [19] Hassan IN, Abuassa N, Ibrahim M. The Sudan conflict: A catalyst for the spread of infectious diseases in displaced populations. Vol. 151, *International Journal of Infectious Diseases*. Elsevier B. V.; 2025. <https://doi.org/10.1016/j.ijid.2024.107326>
- [20] Al-Dar AA, Al-Qassimi M, Ezzadeen FH, Qassime M, Al murtadha AM, Ghaleb Y. Diphtheria resurgence in Sada'a-Yemen, 2017-2020. *BMC Infect Dis*. 2022 Dec 1; 22(1). <https://doi.org/10.1186/s12879-022-07033-x>
- [21] Hussain SF, Boyle P, Patel P, Sullivan R. Eradicating polio in Pakistan: An analysis of the challenges and solutions to this security and health issue. Vol. 12, *Globalization and Health*. BioMed Central Ltd.; 2016. <https://doi.org/10.1186/s12992-016-0195-3>
- [22] Wiesen E, Dankoli R, Musa M, Higgins J, Forbi J, Idris J, et al. Conducting public health surveillance in areas of armed conflict and restricted population access: a qualitative case study of polio surveillance in conflict-affected areas of Borno State, Nigeria. *Confl Health*. 2022 Dec 1; 16(1). <https://doi.org/10.1186/s13031-022-00452-2>